APPENDIX B
DEVELOPMENT OF A WATER QUALITY PLAN FOR THE COLUMBIA RIVER MAINSTEM: A FEDERAL AGENCY PROPOSAL

Cover Memorandum for Appendix B

This is a cover memorandum for Appendix B to the Federal Columbia River Power System (FCRPS) Biological Opinion entitled "Development of a Water Quality Plan for the Columbia River Mainstem: A Federal Agency Proposal." The purpose of this memorandum is to describe the relationship of the actions contained in the attached Appendix B to the Reasonable and Prudent Alternative (RPA), Chapter 9 of the FCRPS Biological Opinion.

In developing the biological opinion, the National Marine Fisheries Service (NMFS), in coordination with the Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (USFWS) and the Federal Action Agencies (U.S. Army Corps of Engineers [Corps]; Bureau of Reclamation [BOR]; and Bonneville Power Administration [BPA]), has considered the respective ecological objectives of the Endangered Species Act (ESA) and the Clean Water Act (CWA). In many instances actions implemented for the conservation of ESA-listed species will also move toward attainment of water quality standards (e.g. reducing total dissolved gas and temperature). The overlap of statutory purpose is extensive, however, there remain additional actions that are appropriate in a water quality plan but which are nonessential for the survival and recovery of the listed species and thus are not required components of the ESA RPA. Further, the water quality plan is likely to require lengthy study and implementation exceeding the duration of this biological opinion.

This appendix charts a course for development of a water quality plan for the mainstem Columbia and Snake rivers to address CWA objectives. The scope of the plan is broader than the FCRPS and would include additional actions to improve mainstem water quality by reducing total dissolved gas and temperature. Some of these actions are expected to be undertaken by entities other than the Federal Action Agencies. Although Appendix B is not itself a water quality plan, it suggests the procedure for development of a plan and identifies actions the plan would likely contain to move toward attainment of water quality standards for the FCRPS.

Appendix B refers to items already called for in the RPA for the FCRPS as a nucleus of actions for the water quality plan. These actions are listed in Table B-2 of the Appendix. These actions are essential for the survival and recovery of the listed species and thus are required components of the RPA.

Appendix B also identifies actions for the FCRPS that further CWA objectives but are not also called for in the ESA RPA. These actions are listed in Table B-3 of the Appendix. These are studies to investigate additional measures to reduced dissolved gas and temperature that may be considered for implementation in the future. These studies are appropriate as ESA conservation measures that will require further ESA consultation when they are developed, analyzed, and proposed for implementation.

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B.1 EXECUTIVE SUMMARY

Fish runs in the Columbia River basin have declined due to a number of factors, including habitat loss across the basin, hatchery production, fish harvest, and hydropower development (Federal Caucus 2000). As a result, 12 stocks of fish in the Columbia River basin that are directly and/or indirectly impacted by the Federal Columbia River Power System (FCRPS) are now listed as threatened or endangered under the Endangered Species Act (ESA). There are also current exceedances of Clean Water Act (CWA) water quality standards (total dissolved gas [TDG] and temperature) that impact fish health and overall beneficial uses in the Columbia River and Snake River mainstem.

The effect of water quality on Federally listed anadromous fish in the basin requires that both issues be addressed in a coordinated manner. Therefore, the Environmental Protection Agency (EPA), the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (USFWS), and the Federal Action Agencies (U.S. Army Corps of Engineers [Corps]; Bureau of Reclamation [BOR]; and Bonneville Power Administration [BPA]) are undertaking efforts to conserve listed species under the ESA and create a nexus of water quality improvements consistent with the CWA.

The ESA and the CWA are complementary statutes offering opportunities to conserve listed species and improve overall system water quality. Both laws stress the importance of maintaining ecosystem integrity. Recognizing that system improvements for fish and wildlife can benefit water quality, EPA, NMFS, USFWS, and the Action Agencies intend to integrate their fish and wildlife and water quality efforts in the form of actions to support the objectives and responsibilities of the ESA, CWA, and other fish and wildlife and water quality statutes such as the Northwest Electric Power Planning and Conservation Act.

This appendix describes current activities and planning for improvements in fish survival that can also serve to improve water quality by reducing TDG and temperature. It also describes efforts that EPA, NMFS, USFWS, and the Federal Action Agencies have decided to undertake now and those they believe can benefit the survival and recovery of listed species. Pertinent portions of this appendix are included in the 2000 NMFS Biological Opinion under Sections 9.6.1.7, Water Quality, and 9.6.5, Research, Monitoring, and Evaluation, as part of the discussion of a reasonable and prudent alternative (RPA).

Over the long term, with a focus on water quality, EPA, NMFS, USFWS, and the Federal Action Agencies—the Corps, BPA, and BOR—commit to developing and implementing a water quality plan that supports TDG and temperature water quality improvements to the Columbia River basin, mainly in the portions of the Columbia, Snake, and Clearwater rivers where Federal dams exist. The water quality plan is anticipated to be consistent with the Columbia River and Snake River mainstem total maximum daily load (TMDL) limits that are currently being developed by EPA, the states, and the Tribes. Water quality plan implementation anticipates that EPA, NMFS, and the Federal Action Agencies will properly integrate implementation of the water quality plan to ongoing TMDL development activities on the mainstem and in the subbasins.

Water quality planning will complement ESA recovery planning efforts by including a development and implementation process consistent with existing planning and review processes, such as the NMFS Regional Forum, scientific peer review, and in some cases, congressional approval.

To successfully implement the water quality plan for the FCRPS, a coalition of Federal, state, Tribal, and other appropriate representatives is necessary to integrate the efforts of all interested stakeholders and provide a connection with ongoing broad-scale coordination efforts in the basin. The water quality plan should include implementation measures to improve water quality. Measures such as ESA and fish and wildlife measures will be coordinated with established processes. These include planning and review processes of the Northwest Power Planning Council (NWPPC), including the Independent Scientific Review Panel, the Columbia Basin Fish and Wildlife Authority, the NMFS Regional Forum, and, if appropriate, the Columbia Basin Forum. Some measures may also require congressional approval. NMFS, EPA, USFWS, and the Federal Action Agencies intend to support implementation of measures that successfully garner approval through these processes. A common approach for selecting water quality, ESA, and fish and wildlife measures to implement will foster coordination among NMFS, EPA, and the Federal Action Agencies, and increase effective use of limited available resources. The outcome of this coordinated approach will be a collection of measures the Action Agencies undertake to serve the agencies' various statutory purposes within budgetary parameters. Recommendations approved via applicable processes could be identified in the water quality plan for implementation.

B.2 WATER QUALITY PLAN

B.2.1 Background

The Federal agencies are committing to development of a water quality plan that is part of the annual planning process (see Section 9.5) for the mainstem Columbia and Snake rivers. At the same time, EPA and the states of Idaho, Oregon, and Washington in coordination with the Columbia River Tribes are embarking on a Columbia River and Snake River mainstem TMDL under court order. EPA will lead development of the portion of the TMDL that addresses the Columbia River mainstem waters from the Canadia border of Lake Roosevelt on the Columbia River, Dworshak Dam on the Clearwater River, and the Brownlee Dam on the Snake River to the Astoria Bridge. The EPA, NMFS, USFWS, and the Federal Action Agencies value consistency of their actions with water quality plans, as well as other plans developed in the Pacific Northwest region. As the Action Agencies make recommendations and decisions, they will take existing water quality plans into account.

The proposed water quality plan anticipates TMDLs consistent with state and Tribal water quality standards and identifies ways that activities can reduce adverse effects on water quality. The Federal Action Agencies intend to participate in the development of the water quality plan to discern further how they can reduce or offset TDG levels and temperature increases associated with their activities. The water quality plan will describe how the listed agencies will participate in this process.

B.2.2 Columbia/Snake River Mainstem System Water Quality Plan

The following outlines how a water quality plan could be developed and implemented. Federal agency representatives developed a water quality plan process to establish a decision process for both operational and structural water quality measures. This process was created to enable decision-making on the biological, cost-effective, and economic implications of water quality measures. Details regarding the process, development, and implementation of a water quality plan may vary, depending on coordination with states, Tribes, and interested persons in the Pacific Northwest.

B.2.3 Project Scope

The water quality plan should consist of a systemwide analysis of the factors that affect temperatures and dissolved gas levels. The analysis will result in development of a suite of recommended actions to improve water quality, using established water quality standards as both the goal and measure of progress for the basin. The Columbia River tributaries and mainstem will be treated as an ecosystem, with the mainstem addressed alongside tributary efforts.

The water quality plan will focus primarily on the physical and operational changes to both Federal and non-Federal dams that may benefit water quality in terms of temperature and dissolved gas while improving the survival rates of ESA-listed species. Other factors that affect water quality, such as grazing, agriculture, forest practices, point sources, land use, mining, and water withdrawals, are being addressed in other forums, including the states' TMDL processes. Discharges to the mainstem that impact gas and temperature and are not covered in tributary TMDLs may be addressed in this plan.

For the initial phase, the plan will address actions from the international boundary on the Columbia River, Dworshak Dam on the Clearwater River, and Brownlee Dam on the Snake River to the tailrace of Bonneville Dam. Future work may include considerations above the international boundary. While the plan will aim to take into account the role of tributaries in mainstem water quality problems, it will not seek specific remedies in the tributaries. Ongoing CWA TMDL processes and other water quality improvement initiatives are under way in many of the tributaries and should not be delayed in anticipation of the plan.

Mechanisms to implement the water quality plan include the 2000 Biological Opinion for the FCRPS and other agreements as appropriate. For non-Federal dams, CWA, the Federal Energy Regulatory Commission (FERC), and appropriate state and Tribal authorities will be involved in implementation.

It is not the primary goal of the water quality plan to target revision of beneficial uses or standards. The purpose is to identify and test hypotheses, implement reasonable actions to improve water quality, and to consider potential revisions to beneficial uses or standards, based on broader societal, legal, and policy considerations (40 CFR Section 131.10(g)) as appropriate. The goals of the water quality plan are as follows:

- To assist in our understanding of systemwide loading capacity and loading allocation by assessing the existing effects at Federal and non-Federal dams and tributaries.

- To provide an organized, coordinated approach to improving water quality, with the long-term goal of meeting water quality standards that the states and Tribes can integrate into their water quality management programs.

- To provide a framework for identifying, evaluating, and implementing reasonable actions for dam operators to use as they work toward reducing temperature and dissolved gas levels.

- To provide a record of the actions that are and are not feasible for structural and operational improvements aimed at improving water quality conditions and meeting water quality standards. This information may provide a basis for future beneficial use and water quality criteria revisions.

- To bring basinwide information into the decision processes regarding dissolved gas and temperature, and to provide technical assessment of a project's relative value in terms of water quality.

- To integrate dissolved gas and temperature work into one process for both Federal and non-Federal dams on the mainstem Columbia River and Snake River system.

B.2.4 Plan Process

Implementation of the mainstem water quality plan could be accomplished as an additional responsibility of existing teams (and/or other basin forums) or the creation of a new Water Quality Team as discussed in Section B.6.3 of this appendix. The new water quality team would link and attempt to integrate actions by the NMFS Regional Forum and the Columbia River Basin Forum, as appropriate, through input and updates on water quality plan implementation. In implementing the water quality plan, the new water quality team would also link the traditional TMDL development and implementation processes to this new effort to improve water quality on the mainstem Columbia River (see Table B-1). The new team would have specific technical TDG and temperature sub-committees.

B.2.5 Participants

The new Water Quality Team may be composed of key technical staff from Federal agencies (EPA, NMFS, USFWS, Corps, BPA, and BOR), states (Oregon, Washington, and Idaho), Columbia River Tribal governments, and non-Federal entities such as public utility districts (PUDs), municipalities, and Idaho Power Company.

B.2.6 Schedule

The first iteration of the water quality plan (including a detailed workplan and timeline) should be completed by the Action Agencies by March 31, 2001, or as soon thereafter as practical.

Table B-1. Decision-making process to implement the water quality plan.

Water Quality Plan Development Process	Relationship to TMDL Planning Process	Who Leads?	Who Assists (Seek Advice/Kept Informed)?	Item Completion Date
Model development and calibration	Identify applicable water quality criteria/goals	Action Agencies	EPA, state agencies, WQT	To be determined (TBD)
Alt. development	identify source of loadings, including natural background	Action Agencies	WQT/IT, Forum	TBD
Modeling, alt. development, and screening	allocate pollutant loadings	Action Agencies	WQT/IT, Forum, state agencies	TBD
alt. screening, alt. analysis	final development of a water quality implementation plan	Action Agencies, Federal execs, state execs, Tribes/IT, Forum	WQT/IT, Forum, Federal execs, state execs, Tribes/IT, Forum	TBD
Decisions/actions	implement the plan	Action Agencies	EPA, state agencies	TBD
Decisions/actions	monitoring and evaluate plan effectiveness	Action Agencies	WQT/IT, Forum	TBD

Note: WQT = Water Quality Team; IT = Implementation Team.

B.3 TOTAL DISSOLVED GAS

B.3.1 Dissolved Gas Goal

The long-term (10 to 15 years) dissolved gas goal is to reach the state and Tribal TDG standard, which is currently 110% for river discharges up to the 7-day, 10-year flow in all critical habitat in the Columbia River and Snake River basins while taking actions to recover listed species in the basin. For anadromous fish, achieving the goal would mean fish passage survival levels consistent with the performance standards for the mainstem projects.

This goal is intended to guide operating and capital improvement decisions relating to TDG created during periods of spill. A systemwide approach is needed to address gas generated at mainstem projects where fish are present, and at upstream facilities (i.e., outside the current range of listed salmon) in both the U.S. and Canada, the five Public Utility District dams on the Columbia River between the Snake River and Chief Joseph Dam, and the Hells Canyon Complex on the Snake River. There are some exceptions noted in the ability to meet the state and Tribal TDG standard.

Without physical modifications to the dams beyond those that are presently under way, the long-term TDG goal cannot be attained between April and August at and between the eight mainstem FCRPS dams. This is a result of the need to rely on spill to safely pass juvenile salmon around those dams. A similar issue exists with Dworshak Dam, where in some circumstances spill is necessary to contribute to the attainment of spring and summer flow objectives for salmon migration and water temperature standards in the Clearwater and lower Snake rivers. Therefore, in the near term, it will be necessary to conduct spill operations that cause exceedances of the 110% TDG gas standard. The Corps will take the actions necessary to implement the spill operation called for in this biological opinion, including spill in accordance with the special TDG conditions set forth below. NMFS will provide technical assistance, as necessary, to support the Corps' actions.

To ensure progress toward the long-term goal, the Corps, BOR, and BPA will also work with NMFS, USFWS, EPA, the Columbia River Tribes, and the states of Washington, Oregon, Idaho, and Montana. This work will take place through an adaptive management process as a part of the water quality plan to accomplish the following:

- Make operational and capital investment decisions at the Federal projects to reduce levels of gas generated by spill and to reduce the reliance on spill as a primary means of juvenile fish passage.

- Fund, implement, and report on adequate physical and biological TDG monitoring to assess compliance with state and Tribal water quality standards and other special conditions that may apply.

- Fund and implement modeling to better assess and act on TDG water quality issues.

The feasibility of meeting the long-term goal will be revisited annually during the water quality improvement planning process.

B.3.2 Special TDG Conditions for Juvenile Fish Passage

At the eight Columbia River and Snake River mainstem projects, spill will be reduced as necessary when the average TDG concentration of the 12 highest hourly measurements per calendar day exceeds 115% of saturation at the next downstream forebay monitor of any Snake River or lower Columbia River dam or at the Camas/Washougal station below Bonneville Dam. Voluntary spill will also be reduced when the 12-hour average TDG levels exceed 120% of saturation at the tailrace monitor at any Snake River or lower Columbia River dams or Dworshak Dam. Spill will also be reduced when instantaneous TDG levels exceed 125% of saturation for any two hours during the 12 highest hourly measurements per calendar day at any Snake River, Clearwater River, or lower Columbia River monitor.

B.4 UPDATE ON SPILL AND 1995 RISK MANAGEMENT

B.4.1 Background

In 1995, the fishery agencies and the lower Columbia Tribes released a paper called Spill and 1995 Risk Management, which presented the benefits of spill for juvenile fish passage, the risks associated with spill-generated gas, and the survival rates of juveniles passing through other routes.

Since 1995, few dissolved gas research projects have continued within the Columbia River Basin. In addition, extensive physical and biological monitoring has been implemented to track the effects of the spill program. An update of the risk assessment for the spill program described in the 2000 FCRPS Biological Opinion is included as Appendix E. The intent of the risk assessment update is to review the research results, and the results of 5 years of monitoring. The update is intended to provide a basis for evaluating the options being considered in the 2000 FCRPS Biological Opinion.

B.4.2 Summary of Appendix E—Risk Assessment for the NMFS Spill Program[1]

Gas bubble trauma (GBT) research efforts have been reduced, reflecting the opinion of decision-makers that sufficient biological knowledge exists to manage the spill program. The main thrusts of research have addressed gas bubble signs and depth compensation for supersaturated conditions.

Work on GBT has characterized its signs, incidence, severity, progression, and relevance. It has been shown that gas bubble signs correlate to exposure, are progressive, and may be useful in understanding their biological implications. Interpretation of signs must be pursued cautiously, however, due to variations in persistence, inconsistencies involving exposure length and water depth, and extreme variability in gas bubble signs.

Depth compensation research has not been extensive in the U.S. portion of the Columbia River, and the results are incomplete and preliminary. However, it does appear that juveniles may get some protection by migrating at depths ranging from approximately 1.5 to 2.5 meters. Results from adult salmonid studies indicate these fish may be negotiating the Columbia River and Snake River migration corridors at depths compensatory to a surface dissolved gas level of 130%. If one accepts these results as representative, it could mean that the biological opinion targets of 115% to 120% dissolved gas pose little problem to migrants.

[1]The following is a summary of Appendix E spill risk assessment. The reader is referred to Appendix E for additional details and references.

Five years of physical dissolved gas and biological monitoring have accompanied implementation of the spill program. Juvenile and adult salmonids, resident fish species, and aquatic insects have been monitored for the incidence and severity of GBT.

Results of physical monitoring have recorded dissolved gas supersaturation levels in forebays and tailraces of each FCRPS project, as well as the impacts of voluntary and involuntary spill. The physical monitoring program has provided a spill and dissolved gas management tool for compliance with state water quality standards waivers.

NMFS concludes in Appendix E that the risk associated with a managed spill program to the 120% TDG level is warranted by the projected 4% to 6% relative increase in system survival of juvenile salmonids. Recent research and biological monitoring results support the findings of the 1995 report which predicted that TDG in the 120% to 125% range, coupled with vertical distribution fish passage information that indicates most fish migrate at depths providing some gas compensation, would not cause juvenile or adult salmon mortalities that would exceed the expected benefits of spillway passage. We find little evidence that this expected survival improvement would be reduced due to GBT-related mortality. The NMFS also concludes that physical and biological monitoring of GBT signs can continue to be used to reflect dissolved gas exposure in adult and juvenile salmon migrants.

B.5 TEMPERATURE

B.5.1 Water Temperature Goal

The long-term goal for water temperature is standard attainment in all critical habitat in the Columbia River and Snake River basins.

In the mainstem Columbia and Snake rivers, attainment of the temperature standard is very complex, due to a number of interrelated factors that affect water temperatures at certain times of the year and to the limited ability to alter water temperature in the mainstem. In the tributaries, attainment of the temperature standard is also complex, due to many of these same factors and the long time needed to realize the temperature benefits of remedial actions (such as riparian restoration). Therefore, in the near term, working with the state and/or Tribe with relevant regulatory authority, the interim goal is to take actions to move toward attaining the standard. Actions to be taken where TMDLs are not yet in place will be consistent with the annual collaborative process described in the following paragraph. The establishment of TMDLs is expected to significantly assist in making progress toward attainment of the temperature standards.

To ensure progress toward the long-term goal, the Corps, BOR, and BPA will also work with NMFS, USFWS, EPA, the Columbia River Tribes, and the states of Washington, Oregon, Idaho, and Montana through an adaptive management process as a part of the water quality plan to achieve the following:

- Make operational and capital investment decisions at the FCRPS projects to move toward attainment of thermal water quality standards.
- Seek consensus on offsite mitigation measures that would contribute to attainment of water temperature standards.
- Fund, implement, and report on adequate physical and biological temperature monitoring to assess compliance with state and Tribal water quality standards and other special conditions that may apply.
- Cooperate with others to fund implementation and modeling to better assess and act on thermal water quality problems and opportunities.
- Develop emergency measures that may be needed to address immediate and acute water temperature problems affecting listed salmon.

The feasibility of meeting the long-term goal will be revisited annually during the water quality improvement planning process.

B.5.2 Water Quality Standards for Columbia River Temperatures

B.5.2.1 Washington Standards: WAC173-201A-130

Washington has a class-based system for determining appropriate levels of protection. The Columbia River, from its mouth to the Grand Coulee Dam, is designated Class A. It is designated Class AA (the highest class) from the Grand Coulee Dam to the Canadian border.

For that portion of the Columbia River from its mouth to the Washington-Oregon border divergence (river mile [RM] 309.3), special conditions are that temperature shall not exceed 68°F (20°C) due to human activities. When natural conditions exceed 68°F (20°C), no temperature increases will be allowed that raise the receiving water temperature by greater than 32.5°F (0.3°C) due to any single source or 33.9°F (1.1°C) due to all such activities combined.

For that portion of the Columbia River from its divergence from the Washington-Oregon border (RM 309) to Priest Rapids Dam (RM 397), special conditions are that temperatures shall not exceed 68°F (20°C) due to human activities. When natural conditions exceed 68°F (20°C), no temperature increases will be allowed that raise the receiving water temperature by greater than 32.5°F (0.3°C). Nor shall such temperature increases at any time exceed t = 34 (T + 9). There is a special fish passage exemption as described in WAC173-201A-060(4)(b).

The Columbia River from Grand Coulee Dam (RM 596.6) to the Canadian border (RM 745) is Class AA. Temperature criteria for Class AA waters are that temperatures shall not exceed 61°F (16°C), due to human activities. When natural conditions exceed 61°F (16°C), no temperature increases will be allowed that raise the receiving water temperature by greater than 32.5°F (0.3°C).

B.5.2.2 Oregon Standards: ORS 340-041- Basin (b)(A)(ii)

Oregon has a use-based system for designating waters for protection. The Columbia River has been designated for salmonid rearing from the mouth to the Deschutes River basin. The stretches in the John Day and Umatilla basins are designated for salmonid rearing and spawning. However, the Columbia River has its own temperature criteria. Therefore, the spawning and rearing criteria do not apply to the Columbia River, even though it may be designated for rearing and/or spawning. The Snake River is designated for salmonid spawning and rearing, and the respective criteria do apply.

No measurable surface water temperature increase resulting from human activities is allowed in the Columbia River or its associated sloughs and channels from the mouth to RM 309 when the surface water temperature exceeds 68°F (20°C). For those basins that contain portions of the Snake River (Grande Ronde, Powder, Malheur, Owyhee), the temperature criteria are 64°F (18°C) for rearing times, 55°F (13°C) for spawning times.

B.5.2.3 Idaho Standards

There are two use designations that apply to the Snake River, cold water biota and salmonid spawning. Cold water biota standards are 71.6°F (22°C) instantaneously and 66.2°F (19°C) maximum daily average. Salmonid spawning standards are 55.4°F (13°C) instantaneously and 48.2°F (9°C) maximum daily average.

B.5.2.4 Colville Tribe Standards

The use designations and corresponding temperature criteria are as follows:

Class I (Extraordinary)—Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting: Temperature shall not exceed 61°F (16°C) due to human activities. Temperature increases shall not, at any time, exceed t = 23/(T + 5). When natural conditions exceed 61°F (16°C), no temperature increase will be allowed that will raise the receiving water by greater than 32.5°F (0.3°C). For purposes hereof, “t” represents the permissive temperature change across the dilution zone; and “T” represents the highest existing temperature in this water classification outside of any dilution zone. Temperature increase resulting from nonpoint source activities shall not exceed 37°F (2.8°C) and the maximum water temperature shall not exceed 50.5°F (10.3°C).

Class II (Excellent)—Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting: Temperature shall not exceed 64°F (18°C) due to human activities. Temperature increases shall not, at any time, exceed t = 28/(T + 7). For purposes hereof, “t” represents the permissive temperature change across the dilution zone; and “T” represents the highest existing temperature in this water classification outside of any dilution zone. Temperature increase resulting from nonpoint source activities shall not exceed 37°F (2.8°C) and the maximum water temperature shall not exceed 65°(18.3°C).

Class III (Good)—Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting: Temperature shall not exceed 70°F (21°C) due to human activities. Temperature increases shall not, at any time, exceed t = 34/(T + 9). For purposes hereof, “t” represents the permissive temperature change across the dilution zone; and “T” represents the highest existing temperature in this water classification outside of any dilution zone. Temperature increase resulting from nonpoint source activities shall not exceed 37°F (2.8°C) and the maximum water temperature shall not exceed 70.3°F (21.3°C).

Class IV (Fair)—Salmonid migration. Temperature shall not exceed 72°F (22°C) due to human activities; T increases shall not exceed t = 20/(t + 2).

B.5.3 Reservoir Operations

Reservoir existence and operation can have strong effects on water temperatures in the reservoir and in downstream reaches. Water temperature conditions have a complex array of effects on salmonids. Intergravel water temperatures affect the rate of embryonic development, with about 50°F degree-days needed for emergence (Weatherley and Gill 1995). Post-emergence growth rates are directly related to water temperature. Water temperatures experienced by outmigrating juvenile salmon have been shown to affect survival (Connor et al. 1998, Muir et al. 1999). Water temperature also indirectly affects salmon survival. Foraging rates of piscivorous fish are directly related to temperature (Vigg and Burley 1991), and the rates of infertility and mortality of several diseases are known to be directly related to temperature (NMFS 1998).

The presence of hydroelectric dams has modified natural temperature regimes in the mainstem Columbia River. Snake River basin reservoirs are known to affect water temperatures in the river (Yearsley 1999) by extending water residence times and by altering the heat exchange characteristics of affected river reaches. Seasonal temperature fluctuations generally decrease below larger reservoirs that are thermally stratified and have hypolimnetic discharges. Downstream temperatures are cooler in the summer as cold hypolimnetic waters are discharged, but warmer in the fall as energy stored in the epilimnion during the summer is released (Spence et al. 1996). Thermal storage provided by the Snake River reservoirs reduces seasonal variations in stream temperatures in much the same way as it reduces seasonal variations in streamflow. There is a documented upward trend in spring water temperature that is consistent with the introduction of storage in upstream reservoirs (NRC 1996). Thus, operation of storage reservoirs affects both the thermal characteristics of the river and the thermally regulated aspects of salmon survival. For this reason, the thermal effects of reservoir operation are an important consideration in developing system operations aimed at protecting and restoring listed salmonids.

An emerging issue is potential water temperature effects on juvenile outmigration timing (NMFS 2000). The hypothesis is that Snake River juvenile fall chinook outmigration timing is delayed by cooler-than-historical water temperatures during incubation and early rearing life stages. This effect may be exacerbated by delayed spawning due to excessively warm fall temperatures. Because Snake River water temperatures and juvenile salmon mortality rates increase from mid-July through mid-September, delaying outmigration timing reduces juvenile fall chinook survival. Migrating adults can be delayed by excessively warm water temperatures (Karr et al. 1998). In addition, fall chinook spawning is inhibited by temperatures above 61°F (16°C) (McCullough 1999). Delay can reduce not only the adult fishes' ability to survive to spawning but also their vigor and fecundity during spawning.

B.5.4 Summer Operations at Dworshak, Brownlee, and McNary Dams

The EPA, NMFS, USFWS, and the Federal Action Agencies intend to abate or offset temperature impacts associated with FCRPS operations. To assess the feasibility of reducing temperatures in ways beneficial to fish, EPA, NMFS, USFWS, and the Federal Action Agencies intend to engage in the following modifications to the summer operations of a number of mainstem dams.

B.5.4.1 Dworshak Dam

During the summer and early fall, cool water releases from Dworshak Dam on the North Fork Clearwater River can offset water temperature problems in the lower Snake and lower Columbia rivers. Given the significance of these cool water releases on the Columbia River and Snake River mainstem and the severe limitations of substantive measures to alleviate high water temperatures in the Columbia River and Snake River mainstem, decisions regarding Dworshak releases may be the most critical in the near-term attempt to moderate water temperature problems for migrating juvenile and adult salmon in the lower Snake River. Therefore, the Federal Action Agencies must commit to a scientifically sound approach to ensure the best use of these Dworshak releases into the Columbia River and Snake River mainstem. These decisions will need to be made in the context of existing regional forums and in concert with the Nez Perce Tribe and the State of Idaho.

B.5.4.2 Brownlee Dam

Cool water releases at Brownlee Dam on the Snake River may provide relief for water temperature problems in the lower Snake River. Commitment on these releases will be developed through the ongoing Section 7 consultation process and through the FERC relicensing process for Idaho Power Company's Hells Canyon Hydroelectric Complex.

B.5.4.3 McNary Dam

Because of the configuration of the Snake and Columbia rivers and the location of McNary Dam, high water temperatures in the juvenile fish facilities have caused fish kills over the years. The Action Agencies should investigate operating measures that can be implemented at McNary Dam when water temperatures and fish conditions reach certain thresholds. These operating measures will serve to help improve juvenile fish survival at McNary Dam and through the system to below Bonneville Dam.

B.5.5 Long-term Temperature Modeling

To assess the system's ability to respond to proposed structural and system operational changes to temperature, numerical modeling of the system will be necessary. Three existing models that have potential for use are described below:

- The EPA Region 10 one-dimensional model

- The COLTEMP model of the Corps Reservoir Control Center

- The dissolved gas abatement study (DGAS) Mass 1 and Mass 2 models

It is the intention of the Federal Action Agencies that the modeling work be coordinated. The Federal Action Agencies shall assess each of the listed models, identifying strengths, weaknesses, data, and resolution requirements for achieving the desired goals. The Action Agencies, through the annual water quality planning process, shall recommend the appropriate model(s) for conducting the analysis.

B.5.5.1 EPA Region 10 One-dimensional Model

The EPA one-dimensional thermal energy model characterizes the relative contribution of reservoirs and tributary flows to changes in water temperatures of the Snake and Columbia rivers. The scope of the modelling effort includes the Columbia River from Grand Coulee to Bonneville dams and the Snake River from the confluence of the Grande Ronde River to its confluence with the Columbia River. The model is a one-dimensional mathematical model of the thermal energy budget that simulates daily average water temperature under conditions of gradually varied flow. The model is based on the energy budget method and uses an efficient numerical solution technique that simplifies the characterization of model uncertainty. Models of this type have been used to assess water temperature in the Columbia River system for a number of important environmental analyses. In 1969, the Federal Water Pollution Control Administration (Yearsley 1999) developed and applied a one-dimensional thermal energy budget model to the Columbia River as part of the Columbia River Thermal Effects Study. BPA et al. (1995) used HEC-5Q, a one-dimensional water quality model, to provide the temperature assessment for the System Operation Review, and Normandeau Associates used a one-dimensional model to assess water quality conditions in the lower Snake River for the Corps (1999).

B.5.5.2 COLTEMP Model

The COLTEMP numerical model is a one-dimensional water temperature model that provides conceptual information about water temperature conditions in Columbia River reservoirs. COLTEMP is not an operational model for regulatory real-time reservoir use. Rather, it is a water management tool used to evaluate how reservoir regulation changes could impact the water temperature structure of reservoirs. The potential changes in the water temperature structure of the reservoirs are taken into consideration during water-release scheduling. The COLTEMP model outputs, however, do not forecast water temperatures.

COLTEMP is a simplified version of the Corps' HEC5-Q water quality model. The model uses the concept of mass balance to move water downstream. The fundamental transport mechanisms are advection (the horizontal movement of a mass of water) and diffusion (movement from a region of higher concentration to a region of lower concentration). External sources determining water temperature include point sources and water withdrawals. Point sources include headwater flow, tributary stream flow, and water withdrawals. The major non-point source is solar radiation. Point sources are represented by daily flow rates multiplied by the corresponding water temperatures. Withdrawals remove mass at the rate of the outflow multiplied by the computed ambient water temperature. As a one-dimensional model, COLTEMP does not consider any degree of thermal stratification within the reservoir. Accuracy of the water temperature output depends on the accuracy of water temperature, weather, and river flow data. In the 1994 interagency Columbia River System Operation Review, the model showed that it adequately represented the one-dimensional thermal dynamics of reservoirs during summer seasons in the Columbia reservoirs.

B.5.5.3 Future Two-dimensional Model

Because reservoir stratification can have effects on salmon survival that cannot be well defined by single-depth monitoring data and one-dimensional models, the Action Agencies, with NMFS and EPA participation, should also develop a two-dimensional model of Columbia River and lower Snake River mainstem water temperature characteristics. Two-dimensional models can provide lateral mixing and temperature information, but they are normally depth averaged and may not be useful for analyzing stratification. In areas suspected or known to have strong stratification, localized three-dimensional modeling may be necessary. To be useful, this model should be capable of estimating bulk average temperatures and providing estimated temperatures on a relatively small two-dimensional scale. This model should also connect the biological aspects of fish presence and specific temperature tolerances to the specific locations of water temperatures to yield a better understanding of water temperature impacts and possible solutions. This model should be fully integrated with the selected one-dimensional input model.

The distribution of flow (velocities) is another important component to understanding and modeling reservoir temperature characteristics. A density current could develop along the bottom of the reservoir, conveying the coldest water through the reservoir with little effect on near-surface water temperature conditions. Further development of the DGAS two-dimensional model (MASS-2) may be appropriate for use in this application and should be further investigated.

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B.6 STRUCTURAL, OPERATIONAL, AND PROCEDURAL MEASURES TO ADDRESS TDG AND TEMPERATURE ISSUES WITHIN THE FCRPS

B.6.1 Structural and Operational Measures

In developing the biological opinion, NMFS, in coordination with EPA, USFWS, and the Federal Action Agencies, has considered the respective ecological objectives of the ESA and the CWA. In many instances actions implemented for the conservation of ESA-listed species will also move toward attainment of water quality standards (e.g. reducing total dissolved gas and temperature). The overlap of statutory purpose is extensive, however, there remain additional actions that are appropriate in a water quality plan but which are nonessential for the survival and recovery of the listed species and thus are not required components of the ESA RPA. Further, the water quality plan is likely to require lengthy study and implementation exceeding the duration of this biological opinion.

Accordingly, action items already in the RPA for the FCRPS, which form a nucleus of actions for the water quality plan, are listed in Table B-2. These actions are essential for the survival and recovery of the listed species and thus are required components of the RPA.

This appendix also identifies actions for the FCRPS that further CWA objectives but are not also called for in the ESA RPA. These actions are listed in Table B-3. These are studies to investigate additional measures to reduce TDG and water temperature that may be considered for implementation in the future. The studies in Table B-3 are appropriate as ESA conservation measures that will require further ESA consultation when they are further developed, analyzed, and proposed for implementation.

B.6.2 Procedural Measures: Decision Process to Implement the Water Quality Plan

There are a number of existing basin forums that address various aspects of salmonid protection and recovery. For example, the NMFS Regional Implementation Forum is principally an ESA-focused intergovernmental forum for regional discussion and decisions on operation and system configuration of the FCRPS. The Columbia River Basin Forum is an entity created by a Memorandum of Agreement among Federal, state, and some Tribal governments that have management responsibilities and treaty rights regarding Columbia River basin fish and wildlife. Although the Columbia River Basin Forum does not have any decision-making authority, it can provide the opportunity for the participants to focus on the most pressing issues to improve effectiveness of regional fish and wildlife recovery efforts. There is also a procedural action in Table B-3 for the Action Agencies to participate in the development of mainstem TMDLs for gas and temperature. In addition, there are ongoing interactions between the EPA, states, municipalities, industry, and Tribes on tributary TMDL development.

Table B-2. List of Clean Water Act and ESA actions in Appendix B that are also called for in 2000 FCRPS Biological Opinion RPA.

FCRPS Project	Description of Action	Action Type	In Biological Opinion Section
	Dissolved Gas Actions		
Systemwide	Development of water quality plan	Plan	9.4.2.4
Lower Granite	Gas fast-track; spillway deflector optimization evaluation	Study	9.6.1.7.2
Little Goose	Gas fast-track; spillway deflector optimization evaluation	Study	9.6.1.7.2
Lower Monumental	Gas fast-track; spillway deflector optimization evaluation; fish passage efficiency and survival	Studies	9.6.1.7.2
Ice Harbor	Post-installation spillway deflector evaluations; fish passage efficiency and survival	Studies	9.6.1.7.2
McNary	Gas fast-track; spillway deflector optimization evaluation; fish passage efficiency and survival	Studies	9.6.1.7.2
John Day	Post-installation spillway deflector evaluations, gas fast-track and fish passage efficiency	Studies	9.6.1.7.2
John Day*	Design and implement spillway end deflector	Design and implementation	9.6.1.7.2
The Dalles	Spill and fish passage survival evaluation; gas fast-track	Studies	9.6.1.7.2
Bonneville	Design/implement gas fast-track and additional spillway deflectors; fish passage efficiency	Implementation and studies	9.6.1.7.2
Systemwide	Complete system gas abatement study	Study	9.6.1.7.2
Chief Joseph	Gas fast-track; spillway deflector design and installation	Implementation	9.6.1.7.2
Grand Coulee	Gas abatement study; evaluate GCL-CHJ gas abatement options	Study	9.6.1.7.2
Libby	Evaluate gas abatement alternatives	Study	9.6.1.7.2
Dworshak	Evaluate gas abatement alternatives	Study	9.6.1.7.2
Systemwide	Total dissolved gas monitoring program	Monitoring	9.6.1.7.2
Systemwide*	Evaluate fixed forebay TDG monitors to determine best location	Study and implementation	9.6.1.7.2
Systemwide	Develop system dissolved gas model	Modeling; study	9.6.1.7.2
Systemwide*	Evaluate gas entrainment divider walls at FCRPS mainstem projects	Study	9.6.1.7.2
Lower Granite	Prototype surface spillway bypass	Construct prototype & study	9.6.1.4.5, 9.67.1.7.2
John Day	Prototype surface spillway bypass	Construct prototype & study	9.6.1.4.5, 9.6.1.7.2

* Action not contained in Appendix B but called for in Sec. 9 of NMFS Biological Opinion.

Table B-2 (continued). List of Clean Water Act and ESA actions in Appendix B that are also called for in the 2000 FCRPS Biological Opinion RPA.

FCRPS Project	Description of Action	Action Type	In Biological Opinion Section
	Water Temperature Actions		
Systemwide	Development of water quality plan	Plan	9.4.2.4
Systemwide	Water temperature data collection/monitoring program	Monitoring	9.6.1.7.2
Systemwide	Develop plan to model system water temperature and operations	Modeling; study	9.6.1.7.2
Systemwide	Evaluate fish ladder water temps.	Study	9.6.1.6.2
Systemwide	Evaluate temp effects on juvenile passage behavior and survival	Study	9.6.1.7.2
Unspecified dam	Conduct comprehensive depth and temp investigation to identify adult passage losses	Study	9.6.1.6.2
Dworshak	DWR NFH water supply improvements to allow temp oper.	Implementation	9.6.1.2.6
Dworshak and L. Snake River dams	Water temp control operations; evaluate effects on adult passage behavior and pre-spawning mortality	Operations and studies	9.6.1.2.6
McNary	Monitor/eval temp in juvenile fish bypass facilities & effects on fish	Monitor and study	9.6.1.7.2
	Tributary Actions		
Systemwide	Coordinate with tributary TMDLs and fund ESA-related TMDL implementation	Study and monitoring; plan implementation	9.6.2.1
Columbia Basin Project	Wasteway water quality monitoring and remediation plan	Study and monitoring; plan implementation	9.6.1.2.7

Table B-3. List of Clean Water Act Actions in Appendix D that are not called for in the 2000 FCRPS Biological Opinion RPA.

FCRPS Project	Description of Action	Action Type	In Biological Opinion Section
Systemwide	Development of Columbia/Snake River TMDLs for dissolved gas and temperature	Study/process	Conservation recommendation 11.8
Grand Coulee	Long-term gas abatement alternative selection study	Study	Conservation recommendation 11.9
Lower Granite	Long-term gas abatement alternative selection study; side channel spillway or raised stilling basin	Study	Conservation recommendation 11.9
Little Goose	Long-term gas abatement alternative selection study; side channel spillway or raised stilling basin	Study	Conservation recommendation 11.9
Lower Monumental	Long-term gas abatement alternative selection study; side channel spillway or raised stilling basin	Study	Conservation recommendation 11.9
Ice Harbor	Long-term gas abatement alternative selection study; side channel spillway or raised stilling basin	Study	Conservation recommendation 11.9
McNary	Long-term gas abatement alternative selection study; side channel spillway or raised stilling basin	Study	Conservation recommendation 11.9
Bonneville	Long-term gas abatement alternative selection study; baffled spillway	Study	Conservation recommendation 11.9
Systemwide	Provide funding to develop tributary TMDLs	Funding	Conservation recommendation 11.11

B.6.3 New Water Quality Team

Perhaps none of the ongoing forums and/or water quality protection activities will provide the desired organizational structure to fully integrate the goals and regulatory requirements of the CWA and ESA in a manner that supports development and implementation of the water quality plan for the mainstem Columbia and Snake rivers. It is also important for EPA, NMFS, USFWS, and the Federal Action Agencies to understand the relationship between the Water Quality Plan and ongoing TMDL planning processes, particularly their relationship with each other and evaluation and implementation of the system improvements and studies. Therefore, final development and implementation of the plan could be accomplished through reformulation of the Water Quality Team, consisting of senior policy analysts and supported by technical staff from Federal agencies (EPA, NMFS, USFWS, Corps, BPA, and BOR); the states of Oregon, Washington, and Idaho; Columbia River Tribal governments; and non-Federal entities such as municipalities and PUDs.

The team would also have specific TDG and temperature technical subcommittees included under the overall umbrella of team actions. The new Water Quality Team could also be a cross-connecting link between the NMFS Regional Implementation Forum and the Columbia River Basin Forum, as appropriate, through input and updates on water quality plan implementation. The new Water Quality Team would review the water quality plan developed by the Action Agencies to help identify key TDG and temperature studies and implementation of structural and operational changes to the FCRPS system, including PUDs. The plan's timeline would provide specific milestones to conclude discussions on technical issues related to structural and operational changes to the FCRPS, consultation with the other basin forums discussed above, and implementation of actions so that they may be considered in conjunction with the 2005 mid-point evaluation under the RPA.

In developing the water quality plan, the new Water Quality Team would incorporate the traditional TMDL development and implementation process with this new effort to improve water quality standards on the mainstem Columbia River (see Table B-1). To accomplish this goal, the new Water Quality Team would seek advice from the NMFS Regional Implementation Forum when necessary. The new Water Quality Team would make funding recommendations for federal projects through the System Configuration Team of the NMFS Regional Implementation Forum, but would also seek other funding for capital structural improvements through traditional agency-focused funding mechanisms. Recommendations by the new Water Quality Team or existing group would undergo the same prioritization and budgeting processes as other actions undertaken or supported by the Action Agencies.

The new Water Quality Team, while having a CWA focus on beneficial uses and on developing and implementing the water quality plan, would interface with ESA compliance by integrating implementation of actions in Tables B-2 and B-3 as appropriate to support water quality improvement in the mainstem, and to complement other related actions and measures that support anadromous fish recovery as well as water quality improvement in the tributaries. As part of the new Water Quality Team, EPA, NMFS, USFWS, and the Federal Action Agencies would review Table B-2 and Table B-3 annually and revise them as needed, after taking into consideration the best available scientific information.

B.6.4 Project Selection Criteria

The possible actions identified in Table B-2 and Table B-3 are at the heart of implementing the water quality plan. Therefore, it is important that both lists contain all appropriate studies and structural and operational changes necessary to comply with and complement the goals of the ESA and the CWA. To appear on these lists, proposals should go through a well-defined screening, prioritization, funding, allocation, and approval process.

The following criteria are proposed for use by the new Water Quality Team to screen Table B-3 items and any other water quality actions identified in the annual planning process. The new Water Quality Team can then provide advice and recommendations to the System Configuration Team of the NMFS Regional Implementation Forum as they prioritize projects as part of the Corps' Columbia River Fish Mitigation Program.

Proposed criteria for evaluating possible actions are as follows:

- How does the proposal meet the tenets of the 2000 FCRPS Biological Opinion and the water quality plan (i.e., how does the proposal complement the two activities)?
- How does the proposal demonstrate substantial progress toward meeting the 110% TDG and temperature standards by the 2005 check-in point?
- If the proposal is a study, how will it increase the existing knowledge base to meet the temperature and/or dissolved gas standard?
- How does the proposal build on existing science to achieve project goals?
- How does the proposal go beyond mitigation for FCRPS impacts to enhance anadromous fish recovery?
- Is the proposal cost-effective?
- Is there consensus among Federal, state, and Tribal representatives to implement the proposal?

B.6.5 Integration of Water Quality Plan with Other Processes

The water quality plan will include possible measures for implementation to improve water quality. These measures, such as ESA and fish and wildlife measures, will be coordinated with established processes. These include planning and review processes of the NWPPC, including the Independent Scientific Review Panel, the Columbia Basin Fish and Wildlife Authority, the NMFS' Regional Forum, and, if appropriate, the Columbia River Basin Forum. Some measures may also require congressional approval.

NMFS, EPA, USFWS, and the Federal Action Agencies intend to support implementation of those measures that successfully garner approval through these processes. A common approach for selecting water quality, ESA, and fish and wildlife measures to implement should foster coordination among NMFS, EPA, USFWS, and the Federal Action Agencies, and increase effective use of available but finite resources. The outcome of these processes is a collection of measures undertaken by the Action Agencies to serve the agencies' various statutory purposes within budgetary parameters. Recommendations approved by applicable processes could be identified in the water quality plan for implementation.

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B.7 MONITORING AND EVALUATION

As part of implementing the water quality plan, the Federal Action Agencies need to install, maintain and operate a complete water quality monitoring network. That network should include a water temperature and dissolved gas data collection protocol. At a minimum, such a protocol should include descriptions of instrument precision and accuracy, measures to ensure quality control, consistent and reliable recording of time and date, and, for data collected in reservoirs, depth. The protocol should also consider data formatting requirements and should be available for downloading from a website. Such information is useful in evaluating the temperature and dissolved gas-related effects of specific operational strategies and may be useful in devising operations that better protect anadromous fish. At this time, there is a comprehensive dissolved gas monitoring network in the Columbia River and Snake River mainstem. However, there are perceived data gaps in a comprehensive temperature monitoring program that could be used to further both CWA and ESA purposes.

Various entities have collected available water temperature data throughout the basin for an array of purposes (Yearsley 1999). Quality assurance and quality control programs ensure that some of these data are collected with sufficient precision, accuracy, and frequency to serve a variety of purposes. For other data, this is not the case. Much of the data collected are from relatively imprecise instruments and may be subject to inaccuracies. For example, turbine scroll case water temperatures may be collected sporadically, using instruments capable of reading to the nearest 1°F. These dial-type thermometers are subject to parallax inaccuracies beyond those of digital measurements and inaccurate reading by observers.

Furthermore, few researchers perceived the need to correlate temperature conditions with current and historical reservoir operations information. Due to reservoir thermal stratification and the physical layout of hydroelectric projects, temperatures in downstream reaches can be affected by reservoir operations. Water temperatures downstream from stratified reservoirs could vary at a given point in time depending on the relative contribution of spill (which comes from warmer near-surface water) to total discharge. If viewed alone, temperature data from such operational effects could appear to be errors in a one-dimensional model. Therefore, it is important to know current and historical upstream project operations, as well as the distribution of water temperatures in the upstream reservoir when estimating the likely downstream water temperature effects of a given operation.

Several FCRPS reservoirs are known to stratify during the summer. Specifically, Lake Roosevelt (Grand Coulee Dam) on the Columbia River and Lower Granite and Little Goose reservoirs on the lower Snake River stratify (Karr et al. 1998). Due to severe gassing problems at Grand Coulee Dam and the very large turbine discharge capacity of the project, the project is routinely operated to minimize spill. Stratification at Lake Roosevelt has very limited potential to adversely affect listed salmon.

In contrast to the situation at Lake Roosevelt, Lower Granite and Little Goose reservoirs lie within currently occupied salmon habitat and can exhibit temperature conditions that could adversely affect salmon survival. Near-surface temperatures have been shown to be much warmer than temperatures near the bottom of the reservoir. Understanding the thermal characteristics of these reservoirs is important to our efforts to devise long-term management schemes to enhance salmon survival.

In order to adequately address temperature monitoring at mainstem reservoirs, the Federal Action Agencies should develop and maintain a model or series of models capable of estimating water temperatures of the Snake River, from Hells Canyon Dam on the Snake River and from Dworshak Dam on the North Fork of the Clearwater River, to the confluence of the Snake River with the Columbia River downstream from Ice Harbor Dam. The models should be developed to function both as planning tools and to provide predicted outcomes in real time. Both one-dimensional and multiple-dimensional models may be needed to fully define the temperature conditions within the reach (see the modeling discussion in Section B.5 of this appendix).

Until a modeling technique is selected, defining a data collection scheme is somewhat risky. That is, if the data needed to effectively drive the model were perfectly understood, better data could possibly be developed at lower cost. Statistical tests may be available to identify the data needs. However, it is clear that both additional water temperature and meteorological data are needed. It is strongly suggested that the EPA, NMFS, USFWS, and the Federal Action Agencies coordinate this effort with EPA and state and Tribal water quality agencies.

As the Snake and Clearwater rivers are rapid, turbulent rivers, it is reasonable to assume that the free-flowing portions of the rivers are relatively isothermic at any given point and time. Existing tri-level thermograph data (Karr et al. 1998) from the Clearwater River inlet also support this assumption. Thus, a single well-placed temperature probe at each selected station in the free-flowing portions of the study streams may accurately define the water temperature at that point.

The number of additional meteorological stations needed to achieve the desired model accuracy is unknown. Given that the geographic scale of weather variations can be quite small, particularly during the summer (for example, summer convective storms), it is unlikely that all errors associated with extrapolation of site-specific conditions could be eliminated with any reasonable number of new stations. Again, a statistical analysis should be conducted to define the most important locations for new meteorological stations. All additional stations should discretely measure all of the meteorological variables necessary to construct a deterministic model of heat flux. Measured variables should include air temperature, relative humidity, barometric pressure, wind speed and velocity, solar radiation, and evaporation rates.

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